Physicochemical and bacteriological analysis of drinking water in public schools of Tarlac City, Central Luzon, Philippines

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ABSTRACT

This study analyzed drinking water in selected public schools in Tarlac City in terms of physicochemical properties and bacterial content. Bottled water, water from dispensers and tap water from faucets were taken for analyses. Seven schools were included in the study which is comprised of 5 public elementary schools, 1 secondary school and 1 tertiary school. These schools were selected because of the high population of students enrolled and being located along busy streets in the city. Findings revealed that of the 21 samples, two registered abnormal color (30 apparent platinum-cobalt unit for both) and high total dissolved solids (>500mg/mL). Moreover, 11 samples out of 21 had shown total coliform and fecal coliform >8 MPN/100mL; 5 samples positive with *E. coli*; and 5 samples with very high HPC (>4000 CFU/mL). The study concluded that some of the water samples are unfit for drinking unless they are boiled. The study recommended that schools voluntarily conduct regular testing of water to ensure safe water for the students. DOH may also conduct random unscheduled water testing to validate voluntary water testing in the schools. Investigation of the incidents of water-borne diseases among the school stakeholders may be carried out in schools found to have positive results to analyze health impact

Keywords: drinking water, total coliform, *Escherichia coli*, fecal coliform, color, pH, chloride, sulfate, total dissolved solids, turbidity

I. INTRODUCTION

The World Health Organization (2008) asserted that access to safe drinking water is a basic human right, important in achieving health, and a part of health policies. In fact, Republic Act No. 9275 declared the Philippine Clean Water Act of 2004, which provided that pursuance of economic policies must take into consideration the protection, preservation and revival of the quality of fresh, brackish and marine water (House of Congress, 2004).

Pollutants can be released into the environment as gases, liquids, dissolved substances, or particulates, and can enter aquatic ecosystems by atmospheric deposition, soil erosion, seepage, runoff, or direct discharge (Regional Aquatics Monitoring Program, 2015). Moreover, weather disturbances such as excessive flooding due to strong typhoons may compromise water quality which could reach a level that will make people sick (Hall, 2015).

In the Philippines, Greenpeace (2007) reported that the sources of water supply include: rainfall, surface water resources and groundwater. Eighty-six percent of piped-water supply systems use groundwater as a source. In terms of groundwater, extensive groundwater reservoir with an aggregate area of about 50,000 sq km is present in the country. Data showed that several groundwater basins are underlaid by about 100,000 sq km of various rock formation. These resources Luzon, Mindoro Island, Negros Island, Northeast Leyte, Ormoc-Kananga basin, Agusan-Davao basin, Occidental Misamis basin, and Lanao-Bukidnon-Misamis basin (Department of Environment and Natural Resources, 2015).

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Groundwater resources are continuously recharged by rain and seepage from rivers and lakes. Naturally occurring hazardous substances may be detected in groundwater such as arsenic and fluoride (DOH, 2007).

Since the country is constantly battered by strong typhoon (Lee, 2015; Rio, 2015) and excessive flooding. Water system infrastructures are subjected to damage which could introduce contaminants into the drinking water (Clark, Hakim, & Ostfeld, 2011). In 2014, when typhoon Haiyan pounded Central Philippines, access to safe and clean water and to sanitation were pressing concerns for survivors. Public water systems had to face the issues on water safety (Manahan, 2014). In October 2015, Central Luzon, which includes Tarlac, was hounded by a strong typhoon which caused excessive flooding.

Aside from tap water, bottled drinking water has also significantly increased over the years. About 3,000 water refilling stations have proliferated nationwide. They sell purified water of comparable quality with bottled water at a lower price (Israel, 2009). In fact, in Tarlac, there are 461 registered water refilling stations in the whole province as of November 2015 record (Department of Trade and Industry, Tarlac, 2015).

The Center for Disease Control and Prevention (2014) explained that people with compromised immune systems should take special precautions with the water they drink. Among healthy individuals, Cryptosporidium can cause illness and severe illness for those with weakened immune systems. In addition, fluoride may be excessively added which has an adverse effect to oral health. Moreover, contaminants in drinking water can lead to adverse health effects, which include gastrointestinal illness, reproductive problems, and neurological disorders. Infants, young children, pregnant women, the elderly, and people with immune systems that are compromised, undergoing chemotherapy, or taking transplant medications, may be susceptible to illness due to the contaminants.

Monitoring drinking water is therefore important and timely since Tarlac has been visited by typhoons and had experienced flooding. It is very much possible that flooding could have damaged water pipes and other structures and may have led to contamination of drinking water.

This study aimed to analyze drinking water in selected public schools in Tarlac in order to ensure safety for students, teachers and other visitors who consume water available in canteens, classrooms, and other sources. Public schools in Tarlac do not conduct regular monitoring of the quality of water so the researchers deemed it important to initiate water analysis in these schools. Hence, this study was conceptualized.

This study aims to determine the physicochemical and bacterial content of drinking water in public schools in Tarlac City. Determining the quality of drinking water in the public schools of Tarlac City in terms of the following: (a) Physicochemical parameters along: Color, pH, turbidity, hardness, total dissolved solids, Chloride, and Sulfate; (b) Bacteriological Content along: Total coliform, Fecal coliform, and Heterotrophic plate count; (c) Compare the results of the bottled water, water in dispensers and tap water; and (d) Draw implications based on the findings to public health.

II. METHODOLOGY

This is a cross sectional study which aims to analyze the physicochemical parameters and bacterial content of bottled water, water dispensers and faucets in public schools in Tarlac.

The seven schools included in the study were selected via purposive sampling. These are located within 2 km radius from the city center. These schools also registered high student population. In addition, the five elementary schools chosen were also included in a study which found lead content on classroom floor dusts beyond the tolerable limit set by US Environment Protection. Water samples from classroom faucets, bottled water sold in the canteen and water from dispensers were collected.

Bottled water samples were taken from the school canteen at 7:30 in the morning right after the delivery to ensure freshness while samples from water dispensers and faucets were collected in standard containers secured from the DOST laboratory where the samples were sent for analysis. The samples for bacteriologic analysis were collected in NASCO bags to prevent contamination from collection and transport. NASCO bags are standard collection bags available at the Regional Standards and Testing Laboratory, DOST Region 3. These bags are sterile.

The research protocol was submitted to the University Research Evaluation Committee (UREC) of Tarlac State University for approval and funding. Upon approval, permission to collect water samples was secured from the school division of Tarlac province and Tarlac City. Upon securing permits, the researchers went to the Regional Standards and Testing Laboratory, DOST Region 3 to get instructions on how the water samples are to be collected.

This is an ISO accredited laboratory where chemists and medical technologists who performed the water analysis were licensed and accredited. NASCO bags were provided by the laboratory to ensure sterility in water collection. Water samples from NASCO bags are for bacterial analysis. After getting instructions from the DOST, water collection commenced.

Physicochemical testing. Three liters of tap water

from the faucets of each of the seven schools were collected in two 1.5 L Coke bottles. Likewise, 3 liters of water from the water dispensers were collected and placed in two clean 1.5 Coke bottles. Three liters of bottled mineral water samples were brought to the DOST laboratory as well. In collecting water from the faucets (tap water), the researchers were instructed by the DOST laboratory medical technologist to let the water flow first for some time before collection. The collection was done in the morning at around 7:30. The faucet selected for water sampling was the nearest one from the main pipe.

For Bacterial testing. NASCO bags that were purchased from the Regional Standards and Testing Laboratory (RSTL) DOST, Pampanga were used as the container for bacterial analysis. This is a standard sterile container issued by the laboratory. Five hundred mL of water from each of the faucet and water dispenser was collected from all seven schools. For the bottled water sold in canteens, one bottle was purchased for bacterial study. Researchers used hand gloves in collecting water samples to avoid water sample contamination. Water samples were collected in the morning from 8-9 AM. Samples were collected from the faucet nearest to the water valve in each school. The water samples were immediately brought to the laboratory to avoid false results due to the time error.

Transport and Preservation of Water Samples. All samples that were collected in NASCO bags, plastic bottle containers and mineral bottles were stored in ice chests to ensure optimal temperature for water freshness. Water samples were transported to the DOST laboratory within 6 hours. This is the standard duration of time that water samples must be analyzed after collection to ensure that the results are not affected by error in collection, transport, and freshness of water samples.

Analysis of Bottled Drinking Water and Water from Dispensers. Water samples from seven school canteens were analyzed in terms of physicochemical properties and bacterial content using standard laboratory procedures in DOST -3.

The frequency distribution, arithmetic mean, and Pearson Product Moment Correlation Coefficient Product were used to facilitate the analysis of data gathered in this study.

Water sampling from the schools selected was only done once so the researchers strongly recommend for another study to validate the conclusiveness of results. Moreover, sampling was only carried in seven public schools. Five of these schools were the ones identified in a previous study to have lead content in floor dusts exceeding the tolerable limit set by the EPA. Again, the researchers recommend to include more schools for sampling in future studies.

III. Results and Discussion

Physicochemical Parameters of Water Samples Collected. In this study, physicochemical parameters of water quality included determining color, pH, chloride, hardness, sulfate, total dissolved solids, and turbidity.

Color is one of the physical parameters of water quality. Ideally, pure water is colorless. Colored water is not aesthetically acceptable to the general public and has significant implications.

Data in Table 1 show that almost all of the water samples subjected for physicochemical analyses had within normal results except for 3B and 3C samples having color beyond the 5-15 units and 5C sample with high total dissolved solids. In the findings, 3B is a sample taken from a water dispenser and 3C is tap water. Both had registered high values which indicate that water sample had an undesirable color. During the time of collection, the researchers themselves had observed that the samples varied in color from the other samples collected by merely using the naked eye.

In addition, 5C sample and 7C (tap water from running faucet) had 556.67 mg/L and 621.67 mg/mL total dissolved solids respectively.

Findings of the study generally indicate normal or desirable physicochemical properties of the water samples from the schools included in the study except for 3B and 3C for color and 5B for total undissolved solids. The results further imply that as far as physical and chemical properties are concerned, water in the schools included in the study had not indicated serious health implications.

Bacteriological Content. The health impact of contaminated drinking water by bacteria could be devastating. It is imperative that drinking water is periodically tested for the presence of pathogenic bacteria to ensure safe water. Table 2 show the results of the bacterial analyses of the water samples.

The table clearly reflects that 5 water samples had indicated total coliform greater than 8 MPN/100mL. According to the Leeds, Grenville & Lanark Health District Unit (2016), total coliform greater than 6 or equal to 6 needs boiling to be safe for drinking. Out of 21 samples, 11 registered >8 total coliform. This indicates the necessity of boiling to ensure the killing of the coliform present in the water samples.

The water samples that had shown presence of total coliform were taken from bottled water, water dispensers and tap water. This implies the need to ensure periodic cleaning of water filters and dispensers.

Tap water must also be boiled prior to drinking (Cinco, 2012).

Table 1
Physicochemical Properties of the Drinking Water

Code	Color	pH	Chloride	Hardness	Sulfate	Total Dissolved Solids	Turbidity
1A	< 5	6.60	10.78	138.78	6.94	316.17	0.05
1B	< 5	6.61	11.76	134.7	8.93	295.00	0.5
1C	10	6.75	48.02	110.88	18.96	390.00	0.25
2A	< 5	5.62	02.94	Not detected	<1	166.67	0.1
2B	< 5	5.27	04.90	Not detected	< 1	48.33	0.1
2C	10	6.71	17.64	159.18	4.12	296.67	2
3A	< 5	5.79	06.86	Not detected	<1	5.00	0.1
3B	30	7.44	20.58	73.47	14.73	286.67	0.9
3C	30	7.06	59.79	112.24	21.53	478.34	0.55
4A	< 5	5.64	02.94	Not detected	<1	6.67	0.1
4B	< 5	5.47	02.94	Not detected	< 1	1.67	0.15
4C	< 5	6.24	22.87	114.29	13.4	288.34	0.2
5A	< 5	6.17	01.95	00.00	01.71	16.67	0.1
5B	< 5	5.37	01.94	00.00	01.22	40.00	0.2
5C	<5	6.65	63.39	73.47	88.03	556.67	0.3
6A	< 5	5.32	08.78	00.00	01.71	36.67	0.1
6B	< 5	5.54	06.83	00.00	01.01	17.50	0.15
6C	< 5	7.38	08.78	71.43	13.74	293.33	0.6
7A	< 5	5.60	08.78	00.00	0.79	15.00	0.15
7B	< 5	5.54	04.88	00.00	24.56	17.50	0.1
7C	< 5	6.22	39.01	163.27	01.22	621.67	0.1

**Color value is based on Platinum Cobalt Unit=Normal Value range is 5-15*
Apparent Platinum Cobalt Unit
** Normal pH is based on Potentiometer Determination=Normal value range is*
6.5 to 8.5
**Chloride normal value is up to 250 mg cl/L*
**Hardness normal value is up to 300 mg $CaCO_3$/L*
**Sulfate normal Value is up to 250 mg SO_4 /L*
**Total Dissolved Solids optimum value is up to 500 mg/L*
**Turbidity normal value is up to 5 Nephelometric Turbidity Unit (NTU)*

Table 2
Results of Bacterial Analyses of Drinking Water

Code	Potability test/Total Coliform (MPN/100mL)	E. Coli	Fecal Coliform (MPN/100mL)	Heterotrophic Plate Count (CFU/mL
1A	<1.1	Absent	<1.1	< 30
2A	>8	Present	>8	150000
1C	<1.1	Absent	<1.1	< 30
2A	<1.1	Absent	<1.1	< 30
2B	>8	Present	>8	160000
2C	>8	Absent	>8	190
3A	<1.1	Absent	<1.1	< 30
3B	<1.1	Absent	<1.1	< 30
3C	<1.1	Absent	<1.1	< 30
4A	<1.1	Absent	<1.1	< 30
4B	>8	Absent	>8	< 30
4C	>8	Present	>8	38000
5A	<1.1	Absent	<1.1	< 30
5B	<1.1	Absent	<1.1	< 30
5C	<1.1	Absent	<1.1	< 30
6A	>8	Absent	>8	< 30
6B	>8	Present	>8	34000
6C	>8	Present	>8	4200
7A	>8	Absent	>8	< 30
7B	>8	Absent	>8	< 30
7C	>8	Absent	>8	< 30

*MPN –most probable number
*CFU- colony forming unit

These water samples were further tested for the presence of *E. coli* which is a more pathogenic bacterial strain that contaminate water.

Further test for *Escherichia coli*, which poses greater health threat than the coliform bacteria combined showed positive results for 1B, 2B, 4C, 6B and 6C water samples. These are water samples from water dispensers and faucet. Presence of *E. coli* indicates fecal contamination which could be from humans and animals. This endangers the health of anyone who drinks the water, especially those with a compromised immune system. An immediate investigation must be conducted to eliminate the source of contamination. Water with *E. coli* must be boiled even if the water is used for preparing food and brushing teeth (DOH, 2016).

For the presence of fecal coliform, 1B, 2B, 4B, 4C, 6A, 6B, 6C, 7A, 7B & 7C had indicated positive results. These results further provided evidence that water taken raw without boiling would pose health threats to consumers.

Further tests using the heterotrophic plate count generated results higher than 30 Colony Forming Unit (CFU)/mL for samples 1B, 2B, 4C, 6B and 6C. Gandham (2016), HPC must be less than 500 CFU/mL to indicate good water quality (Penn State College of Agricultural Sciences, 2016).

The results of the water analyses from bottled water, water from dispensers and tap water were compared and the results are shown in Table 3.

Table 3
Comparison of Physicochemical Properties of Drinking Water

Code	Color	pH	Chloride	Hardness	Sulfate	Total Dissolved Solids	Turbidity
Bottled Water							
1A	-	-	-	-	-	-	-
2A	-	-	-	-	-	-	-
3A	-	-	-	-	-	-	-
4A	-	-	-	-	-	-	-
5A	-	-	-	-	-	-	-
6A	-	-	-	-	-	-	-
7A	-	-	-	-	-	-	-
Water from Dispenser							
1B	-	-	-	-	-	-	-
2B	-	-	-	-	-	-	-
3B	+	-	-	-	-	-	-
4B	-	-	-	-	-	-	-
5B	-	-	-	-	-	-	-
6B	-	-	-	-	-	-	-
7B	-	-	-	-	-	-	-
Tap Water							
1C	-	-	-	-	-	-	-
2C	-	-	-	-	-	-	-
3C	+	-	-	-	-	-	-
4C	-	-	-	-	-	-	-
5C	-	-	-	-	-	+	-
6C	-	-	-	-	-	-	-
7C	-	-	-	-	-	+	-

*within normal parameter = -
*outside normal parameter= +

Based on the table above, tap water had shown the most number of positive results, particularly in color and in the presence of total dissolved solids. Water from dispensers had shown one positive result while all results generated from bottled water had shown negative results. It is safe to infer that drinking water from faucets must be boiled before ingestion. Water dispensers must be cleaned well to avoid contamination.

Data in the table show that bottled water had generated the least number of positive results in terms of bacterial content. Only two samples had positive results but all were negative for *E. coli*, the most virulent member of the coliform genera. Water samples taken from water dispensers and faucet had shown positive results for total coliform. In fact, three samples from both sources had shown the presence of E. coli.

Based on the over-all findings, bottled water in all schools included in this study is safe for drinking. But water from dispensers in three schools is not safe for drinking unless boiled. This is also true in the faucets of three schools.

Findings of the study had provided evidence that drinking water available in public could potentially compromise human health. Although results generated in the study are only true for water samples submitted, this raises doubt as to the quality of other batches coming from the same sources or manufacturers. The findings of the study convey the necessity of careful and strict compliance to the guidelines instituted to ensure safe water to the public. Business owners have to set up their own quality control protocols that should be strictly followed by all workers within their companies. It is also imperative that owners and employees be thoroughly oriented on the health threats from improperly prepared commercial water.

Table 4
Comparison of Bacterial Content of the Drinking Water

Code	Potability test/Total Coliform (MPN/100mL)	E. Coli	Fecal Coliform (MPN/100mL)	Heterotrophic Plate Count (CFU/mL
Bottled Water				
1A	-	-	-	-
2A	-	-	-	-
3A	-	-	-	-
4A	-	-	-	-
5A	-	-	-	-
6A	+	-	+	-
7A	+	-	+	-
Water from Dispenser				
1B	+	+	+	+
2B	+	+	+	+
3B	-	-	-	-
4B	+	-	+	-
5B	-	-	-	-
6B	+	-	+	-
7B	+	+	+	+
Tap Water				
1C	-	-	-	-
2C	+	-	+	-
3C	-	-	-	-
4C	+	+	+	+
5C	-	-	-	-
6C	+	+	+	+
7C	+	+	+	+

IV. CONCLUSION

Most water samples had normal physicochemical properties except for two samples out of 21 with abnormal color and two samples with high total dissolved solids. Some water samples had high total coliform count; had indicated the presence of *E. coli*, fecal coliform and high Heterotrophic Plate Count and bottled water is the safest drinking water available in all schools. Some samples from water dispensers were not fit for drinking unless boiled. Tap water samples also showed presence of pathogenic coliform.

Drinking water in schools must be regularly monitored to ensure safety of the consumers. DOH must develop a mechanism of checking whether the schools strictly comply with the policies set forth by the local government. DOH must conduct random tests to ensure that water is safe any time in the schools.

Water from dispensers and tap water must be boiled prior to drinking because some samples had generated positive bacterial content and owners of drinking water businesses must set up their own quality control protocol to ensure safe water for the public. Owners and employees must be thoroughly oriented about the potential harm that may compromise the health of the customers. Another study must be done to include more schools for sampling since the present study only collected samples from seven public schools.

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Associate Professor Mina is a member of professional societies like The Philippine Association of Chemistry Teachers, Organic Chemistry Teachers' Association, Philippine Environmental Mutagens Society, Inc., Natural Products society of the Philippines, OHSEC Institution of Fire and Safety Practitioners, Samahan ng mga Edukador sa Pilipinas and Philippine Association of Extension Program Implementors, Inc.